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Three Tone PPI

24917

(None)

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Massachusetts Inst. of Technology, Cambridge, Mass.

Office of Scientific Research and Development, NDRC, Div 14

R-834

(None)

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A method to overcome a limitation of a radar picture on the screen of a cathode ray tube is described. The three-tone PPI overcomes this limitation in part by providing two limit levels; one for general land signals, and one for the more prominent targets. This is accomplished by either a time division method or by methods which divide, separately amplify, and later mix the two classes of signals. The result is a composite picture which shows general land signals and built-up areas contrasting in brightness on the cathode ray tube. The range of signals, was found to center around twenty db difference between those signals which would normally be termed land background and those which would be termed "bright" under typical adjustments.

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Electronics (3) Tubes, PPI (95239)

Electronic Tubes (8)

R-3-8

Air Documents Division, T-2
AMC, Wright Field
Microfilm No.
RC993 F24917

242,3

THREE TONE PPI

REPORT
934

RADIATION LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE - MASSACHUSETTS

NDRC
Div. 14
OEMsr- 262

Radiation Laboratory

Report 934 March 20, 1946

THREE TONE PPI

Abstract

A Three-Tone PPI is intended to overcome a limitation in the usual presentation of a radar picture on the screen of a cathode ray tube. This limitation is the result of necessary limiting in the receiver and the characteristics of the cathode ray tube, permitting little contrast in brightness between general land signals and the strong signals resulting from built up areas. The three-tone PPI overcomes this limitation in part by providing two limit levels; one for general land signals, and one for the more prominent targets. This is accomplished by either a time division method or by methods which divide, separately amplify, and later mix the two classes of signals. The result is a composite picture which shows general land signals and built up areas contrasting in brightness on the cathode ray tube. A number of photographs are included, indicating the results obtained. The range between the weaker "Background" signals and the stronger "Target" signals has been found to center around 20 db. There is included a complete schematic of a Three Tone attachment for the AN/APS-15A system.

F. N. Barry

Approved by:

C. J. Sherwin
Leader, Group 62

L. J. Haworth
Head, Division 7

Title page
7 numbered pages
12 pages of figures
Appendix

THREE TONE PPI

Introduction.

A "Three Tone PPI" is a device which permits the simultaneous presentation on the cathode ray tube screen of a radar system of the signals from land return which provide the general mapping of land-water boundaries, and at the same time present on the screen the signals which result from cities, built up areas, and other prominent targets, distinct from the general land mapping. The general operation of such a device, and also the origin of the term "three tone PPI" may be shown by Fig. 1. Fig. 1a shows diagrammatically the indicator presentation of a radar system in which the receiver I.F. gain control has been adjusted to a rather high value. Signals returning from water are so weak that the indicator presents them essentially as "black", while practically all land return signals are of such value as to cause limiting in the receiver and are therefore presented on the indicator tube as a more or less uniform "white". It is true that if limiting did not occur in the receiver this condition would not exist, but in the present state of the art it is not only necessary but very desirable that limiting does take place in the receiver-indicator system. This is necessary because the intensity of return echoes from various types of targets varies over a wide range. Neither the cathode ray tube itself, nor the receiver-indicator system in general are capable of presenting this wide range of return signals in their corresponding true values of light output on the face of the cathode ray tube.

Limiting in the receiver has therefore been almost universally adopted in radar systems so that weak signals may be presented on the indicator without having these weak signals completely obscurred by the stronger echoes. It will be noted that in Fig. 1a no cities or other prominent targets are seen since these are limited at the same level as the other land signals. Fig. 1b represents the same indication as Fig. 1a, but here the receiver I.F. gain control has been adjusted so that only strong signals, such as those from cities, are presented on the cathode ray tube. However, now the general land-water mapping is lost. A radar operator may at frequent intervals adjust the I.F. gain control to first one, and then the other value, and thereby obtain the types of information shown in both Fig. 1a and Fig. 1b. More often this process is regarded as an added complication for an already busy operator. A "Three Tone" circuit accomplishes the same thing continuously and automatically as indicated in Fig. 1c. Here water is "black" as before. The general land return is indicated as moderate illumination of the cathode ray tube, or "gray". The stronger signals from cities etc., are indicated by a greater light intensity, or "white".

A "Three Tone" indication may be obtained in a number of different ways. However, these may be divided into two general classifications. (1) Those in which the receiver-indicator operating conditions are periodically altered from those resulting in the "gray" of the land-water indication, to the conditions required for the "white" strong signal indication. This class of circuits may be termed switching. (2) The second classification consists of those circuits in which no switching takes

place, usually a circuit in which the signals are divided at some point in the receiver, amplified in a different manner, and later re-combined. The radar pictures resulting from typical circuits of either classification are almost indistinguishable from each other as viewed on the cathode ray tube screen.

For the remainder of this report the conditions and signals resulting in the "gray" of land-water boundaries will be referred to as "background" signals or conditions. The stronger signals representative of cities which are presented as "white", and the conditions resulting in their indication, are referred to as "Target" signals or conditions.

"Switching" Type Circuits.

In order to obtain three tone presentation by this class of circuits it is necessary to change periodically the operation of the receiver and video amplifier so that for background signals the I.F. amplifier is operated at a relatively high gain, while for target signals the I.F. gain required is much lower. At the same time it is necessary to change the video limit level so that the background signals result in a lower value of video output signal than do the target signals. The relationship is given in the following table:

Condition	Signals to be		Video Limit	
Condition	Amplified	I.F. Gain	Level	Indication
1	Background	High	Low	Gray
2	Target	Low	High	White

It is usually most desirable to switch at a rate corresponding to the trigger repetition rate of the radar system so that for one trigger the receiver will be in condition 1, the second trigger will be in condition 2, etc. Thus the receiver will be in conditions 1 and 2 for equal lengths of time, and the switching will be synchronous with the trigger repetition rate. Unequal time division between the two conditions and non-synchronous switching have both been tried, but both are inferior. Non-synchronous switching is particularly unsatisfactory.

Typical of the switching type circuits is the one used experimentally and proposed for manufacture for the AN/APS-15A radar system. The receiver and video amplifier of this system before its modification for three tone operation are shown in block diagram form in Fig. 2. The I.F. gain control in this receiver consists of a potentiometer supplying a variable negative bias voltage to the grids of the first two I.F. amplifier tubes. The video limiter is a very frequently used circuit consisting of a pentode video amplifier tube (6AC7). The control grid is at approximately zero potential in relation to the cathode. The screen grid is at a fixed positive potential. In absence of an input signal, the tube will draw a "standing" plate current through the plate load resistor. The plate will therefore be at a negative potential in relation to the plate supply voltage. A negative video signal is fed to the control grid from a diode second detector. This video input signal drives the control grid negative until at about -3 volts the tube is cut off. At this point the plate potential will have risen to the plate supply potential. As the control grid becomes more negative the input signal has no further effect on the tube's plate potential since the plate current is already zero.

Figure 3 shows in a combination block diagram and simplified schematic the application of three tone circuits to the receiver of Figure 2. A negative trigger which occurrs at the end of each indicator sweep is fed thru isolating diodes to the multivibrator. Although this is an a.c. coupled circuit which will operate at a low rate if not triggered, it operates as a scale of two circuits when triggered at normal repetition rate frequencies. Negative square waves of opposite phase are fed to the grids of switch tubes V-1 and V-2. Thus, when V-1 is conducting, V-2 is cutoff and visa versa. When V-1 is conducting the potential at point "A" will be determined only by V-1, R-1 and R-2, since no current is flowing thru V-2 and R-3. On the other half of the switching cycle V-2 will be conducting, and the potential at point "A" will be determined only by V-2, R-3, and R-2. R-1 is the "background gain control" and R-3 is the "Target gain control". The bias voltage at point "A" may be adjusted during one half of the switching cycle by the target gain control independently of the background gain control setting, and likewise during the opposite half cycle only the background gain control determines the bias voltage and therefore the receiver gain.

Simultaneously with the switching of the receiver I.F. gain as described, the video limit level is changed by the circuits associated with a switch tube V-3, and a diode V-4 in the following manner:

The same square wave which is fed to the grid of V-1, the background gain control switch tube, also is fed to the grid of V-3. During the half cycle when V-1 and V-3 are cut off, no current will flow thru R-4 and R-5. Thus, the diode cathode will be at the limiter tube plate supply potential, and if cut off by a sufficiently large video signal, the plate of the limiter tube will rise to the plate supply potential in the normal manner. During the opposite half cycle when V-1 and V-3 are conducting, current will flow thru R-4 and R-5. The cathode of the diode V-4 will be at a potential negative with respect to the plate supply, but less negative than the limiter "standing" plate potential. The diode under these conditions is still nonconducting. When a negative video signal is applied to the limiter grid, its plate potential will rise in a normal manner until the limiter plate potential equals the potential on the cathode of the diode. At this point the diode will conduct and effectively prevent the limiter plate from rising any farther. In this manner two video limit levels are obtained, but since the "standing" potential of the limiter plate is not changed, no undesirable square wave pedestal is introduced in the video output signal. The ratio of the smaller limit level to the larger may be adjusted by R-6 in the cathode of V-3. The optimum ratio has been found to center around two to one. The diode V-4 may be a germanium crystal whose back resistance at 30 volts is at least 50,000 ohms. Such crystals have been successfully used in this position in a number of three tone equipments.

Circuits similar to those described have also applied to the AN/APQ-7 radar system. A modification for the AN/APQ-13 system differs only in that the method of I.F. gain control used in this system consists of a variable resistor in the cathodes of the first two I.F. stages. It was necessary therefore to arrange the three tone switch tube circuits in order that the gain variation square waves would be applied at the I.F. tube cathodes. However the basic circuits are the same.

What is probably the first three-tone circuit, described in Radiation Laboratory report #91-6/24/44 by R. Sherr, employed a switching circuit in which only the I.F. gain was switched. In order to obtain a satisfactory contrast in brilliance between the target and background signal, which in this case would be dependent only on the increased number of times the target signals excite the cathode ray tube screen in relation to the background signals, it was found desirable to arrange the switching sequence so that the target signals were amplified for a period of about five times as long as the period in which the background signals were amplified. This has a twofold disadvantage because of the effective reduction of repetition rate for background signals to one-sixth. (1) The detection of weak signals is impaired by the reduced repetition rate; (2) Any tendency toward spoking due to the relationship of the angular velocity of the sweep to the repetition rate is aggravated in direct ratio to the effectiv reduction in repetition rate.

Non-synchronous systems using mechanical relays have proved unsatisfactory even with relays which operate as high as 400 switches per second. This is in part due to beats which are observed on the cathode ray tube between the switching frequency and the repetition rate, or some harmonic relationship between these two.

Non-Switching Type Circuits.

Included in this classification is the "Double I.F." system shown in block diagram form in Fig. 4. Here the I.F. preamplifier output is divided into two parts and fed through two separate I.F. amplifiers, separate second detectors, and into two separate limiters. The output of the two limiters are added, and the composite signal is fed through a video stage to the cathode ray tube. One channel, which may be termed the background channel, is adjusted to a relatively high I.F. gain and therefore limits at small values of input signals. The other channel, which may be called the target channel, is adjusted to lower I.F. gain so that it effectively does not amplify the weaker signals, and only the stronger target signals are limited. The output of this limiter is added to the output of the background channel which produced a total video voltage about twice as great as that from the background channel alone. The exact ratio of the amplitudes of the limited background signals to the limited target signals may be changed by an adjustment which changes the standing current in one of the limiters by varying its screen voltage. Thus there are two controls and one adjustment which correspond in function exactly to the two controls and one adjustment on the switching type circuits described previously. The target channel I.F. gain control is the Target Gain Control, the Background I.F. gain control is the Background Gain Control, and the screen voltage adjustment on one of the limiters corresponds to R-6 of Fig. 3 in function.

The I.F. input versus video output of an actual system using these circuits is shown in Fig. 5.

It should be noted that there is a fundamental difference in the switching systems and the "two receiver" system. In the latter system a composite video signal actually exists, while in the switching systems the signals are mixed only by the persistance of the cathode ray tube and the eye. The "two-receiver" system was used as an attachment to an AN/APS-15A radar system for extensive flight tests to determine the value of three-tone equipments. Its performance was completely satisfactory. An attachment of this kind was also built for the AN/APQ-13. The only important objection to this type is the cost in terms of number of tubes and the complexity of the circuits required. All of the photographs attached to this report were taken on a "Two-Receiver" Three-Tone attachment on an AN/APS-15A system.

Another three-tone circuit of the same general type was developed by the Bell Telephone Laboratories for the AN/APQ-13 system. In this case the second detector has a considerable range of linear detector output above that value of output normally required for limiting so that it is practical to take the unlimited second detector output, divide it into two video amplifier channels, one with a high gain, one with low, and mix again in the outputs of two separate limiters. The "Target" video amplifier is actually operated with the grid cut off in the absence of a signal so that it amplifies only the "tops" of the stronger signals.

Still another circuit in which some development work was done in the Radiation Laboratory is the "Two Limiter" method. This circuit also depends on the ability of the second detector to supply a rather wide range of linear output above that normally required by the limiter. This circuit consists essentially of two limiter tubes in parallel, one arranged to be sharp cutoff in the normal manner and the other effectively "remote cutoff".

All of the systems described effectively have a step in the relationship of input signals to the resulting light output of the cathode ray tube. That is, the effective output increases with increasing input up to a certain value, remains constant for a time as the input is further increased, then with still greater input, increases again and finally comes to a final limiting value. This may be seen by examining Fig. 5. There have been proposed a number of circuits in which the output signal increases continuously, though in a non-linear manner, with increasing input signal. Included in this group is the logarithmic receiver developed by Group 61 of the Radiation Laboratory and which predated the first "Three-Tone" attachment. Also there have been proposed circuits employing diodes or crystals as non-linear elements to operate at video frequencies and give a logarithmic or other non-linear input-output relationship. It is believed that none of these have been tried in an actual operating radar system and no information is available of the comparative merits of such a device and circuits of the type with which this report is primarily concerned.

Results.

A large number of PPI photographs have been taken in order to obtain information on the operation of three-tone PPI. A few of these

are shown in Figures 6 to 10. In all cases the range markers are five mile markers.

Figs. 6 and 7 are a pair of photographs taken under the same conditions with and without three tone. These two photographs show in an exceptionally striking manner, not always so apparent under other conditions of terrain and signals, the benefits which may be derived. These two pictures are taken near Portland, Oregon. The dark line running approximately horizontally across the pictures is the Columbia River. The plane's heading, as shown by marker , is slightly west of north. Fig. 6, the non-three tone picture, clearly shows the Columbia River, the smaller Willamette river running approximately from south-east to north-west where it joins the Columbia, the hills to the south-west and to the east, but gives little indication that an industrial area lies below the plane. Fig. 7, the three tone picture, clearly indicates business sections of the city of Portland at about five miles (the first marker) and a seven o'clock position. Two Columbia river bridges are visible at five miles and 10 o'clock, while slightly to the east is Vancouver, Washington, site of shipyards and aluminum plants. At closer range to the plane are residential areas of Portland, which give scattered bright targets. An interesting effect causes the two spokes visible on the three tone picture. Here the generally regular street pattern is parallel to these spokes, and buildings which would not normally show as bright targets act as a series of "corner reflectors" and result in the spokes. This effect is noticeable to a greater or lesser extent in all cities with a regular street pattern. This effect also suggests that an individual target will or will not show as a bright target depending on the aspect from which it is viewed. This is very true. In making several flights over the M.I.T. buildings in Cambridge, Massachusetts from different directions it was found that in the minority of cases did this group of buildings show up as bright targets. More complex targets, such as shipyards, almost invariably show up as bright.

Fig. 8 shows a three tone photograph of Boston, Massachusetts. Here again the range marker is at five miles. South of the plane's position is the Charles River Basin, with three bridges showing. The nearest bridge is the one variously called "Cambridge" or "Longfellow". The second is the Harvard Bridge, the third at the point where the basin narrows down to the Charles River is the Cottage Farm Bridge. At this point, on the north shore of the river, a number of warehouses show up as bright targets. The "gray" area, on the south-east side of the basin surrounded by brighter areas, is the Boston Common and Public Gardens. To the north and east of the plane's position is the Mystic River, with several of its bridges.

Fig. 9 was taken over the San Francisco Bay area. The plane's position was approximately over the Oakland end of the San Francisco Oakland Bridge. The plane's heading is north-west, magnetic north, rather than true north, is "up" on the picture. Clearly visible are the Golden Gate, and San Francisco Bay bridges, the runways of the airfields on Terminal Island and at Alameda, the breakwater at Oakland,

the industrial area to the north of Richmond. The small targets in the bay are shipping. Some sea return shows at close range.

Fig. 10 is of the area between Gary and East Chicago, Indiana. This photograph shows clearly the contrast which may be obtained between water, general land return, and built up areas.

Figures 11 and 12 are a pair of photographs of the Boston area taken from a few miles north of the city. They are intended to show the additional information provided by three-tone operation. Fig. 11 is a non-three-tone photograph and Fig. 12 is a three-tone photograph. The cluster of bright targets on the range marker at approximately a two o'clock position is Lynn, Massachusetts.

The range of signals, based on a series of measurements, was found to center around a twenty d.b. difference between those signals which would normally be termed land background and those which would be termed "bright" under typical adjustments.

It is believed that while a three-tone device is no cure-all for the problems encountered on airborne radar, the additional information simultaneously presented is of distinct advantage.

Description of Three-Tone Attachment for AN/APS-15A.

Fig. 13 is a complete schematic diagram of the electronic switching attachment developed for the AN/APS-15A. This is the same circuit shown in simplified form in Fig. 3. This attachment is intended to be mounted at the side of the receiver in the Receiver-Indicator box. Most of the connections are made to the system by inserting an adapter plug, J-2, between the receiver and the receiver's power supply cable. The only other operations for installation are soldering two wires and the installation of the two controls. The target gain control and the on-off switches are ganged so that the switches operate when the target gain control is first turned from an extreme counter-clockwise position. The system's I.F. gain control, "Receiver Gain", is removed and replaced by R-23 which then functions as the I.F. gain control for normal operation, and as the background gain control for three-tone operation. For normal operation, current still flows through one side of the switch tube, V-4 but the multivibrator is rendered inoperative by cutting off the grid of the proper side. Other features will be apparent from an examination of the diagram, or the simplified diagram, Fig. 3.

F. M. Barry
December 10, 1945

APPENDIX

Radiation Laboratory drawings pertaining to Three-Tone PPI.

A-14278A Schematic of Electronic Switching Attachment for AN/APS-15A.
A-14448A-J Complete Mechanical and Wiring Diagrams for above.
A-14088A Earlier Miniature Tube Switching Attachment for AN/APS-15A.
B-13732A Superceded by A-14088A.
A-13617A Schematic of Electronic Switching Attachment for AN/APQ-13.
B-13840A Schematic of "2nd Receiver" Attachment for AN/APQ-13.
C-13978A Power Supply for above.
X-6891 Characteristics of Power Supply, Drawing C-13978A.
T-5289 Simplified Schematic, Attachment for AN/APQ-7.
X-6866A Performance Curves, 2nd Receiver Method for AN/APS-15A.
T-6341A Schematic of Modified Limiter System Attachment.
X-6917A Performance Curves for T-6341A.
B-13326A Mechanical Switching Attachment for AN/APS-15A.

Radiation Laboratory Reports.

91-6/24/44 "A Radar Receiver for PPI Presentation for Airborne Systems" - R. Sherr.

63-3/22/45 "Installation Instructions for Three Tone PPI Attachment for APS-15A" - Britton Chance. (This is not the same attachment for AN/APS-15A described in this report).

BLOCK DIAGRAM OF AN/APS-15A RECEIVER
(AFC CIRCUITS OMITTED)

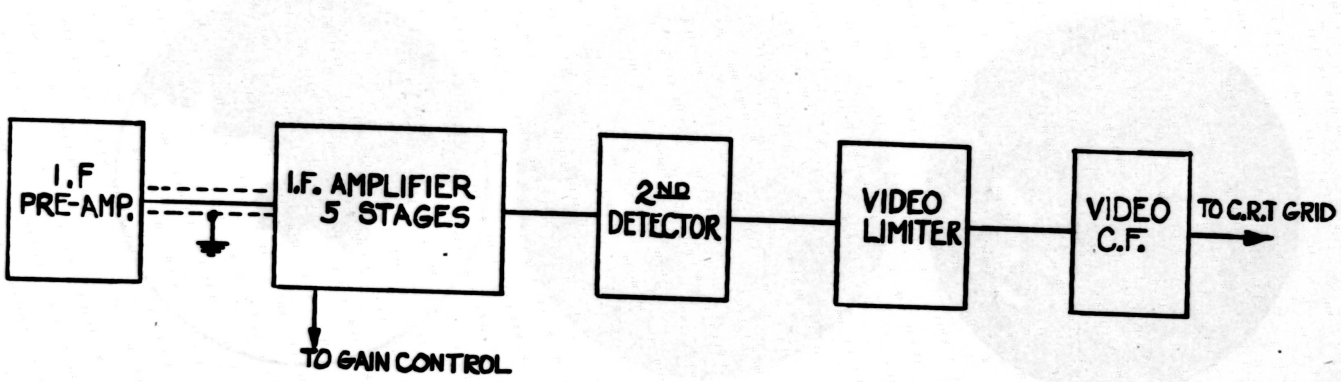

FIG. 2

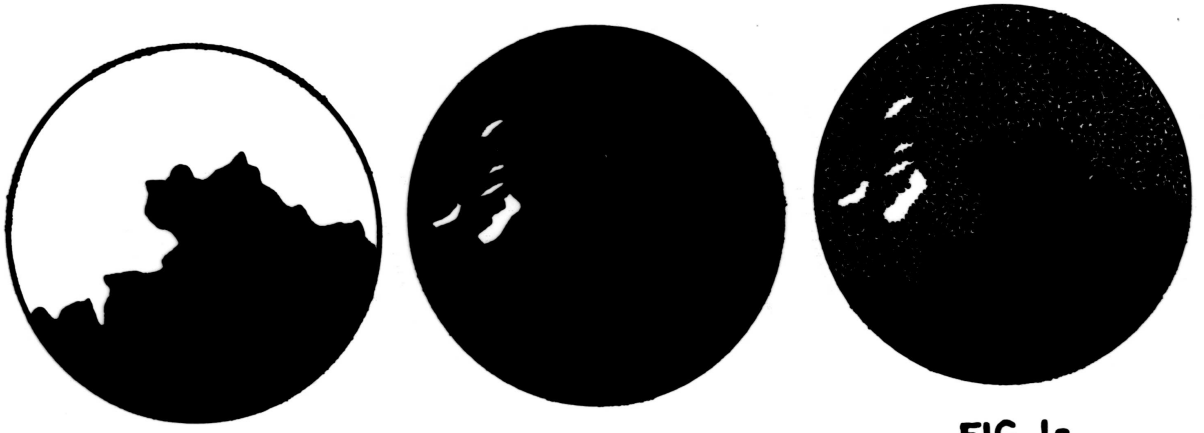

FIG. 1A

FIG. 1B

FIG. 1C

ELECTRONIC SWITCHING THREE TONE ATTACHMENT
FOR AN/APS-15A
SIMPLIFIED DIAGRAM

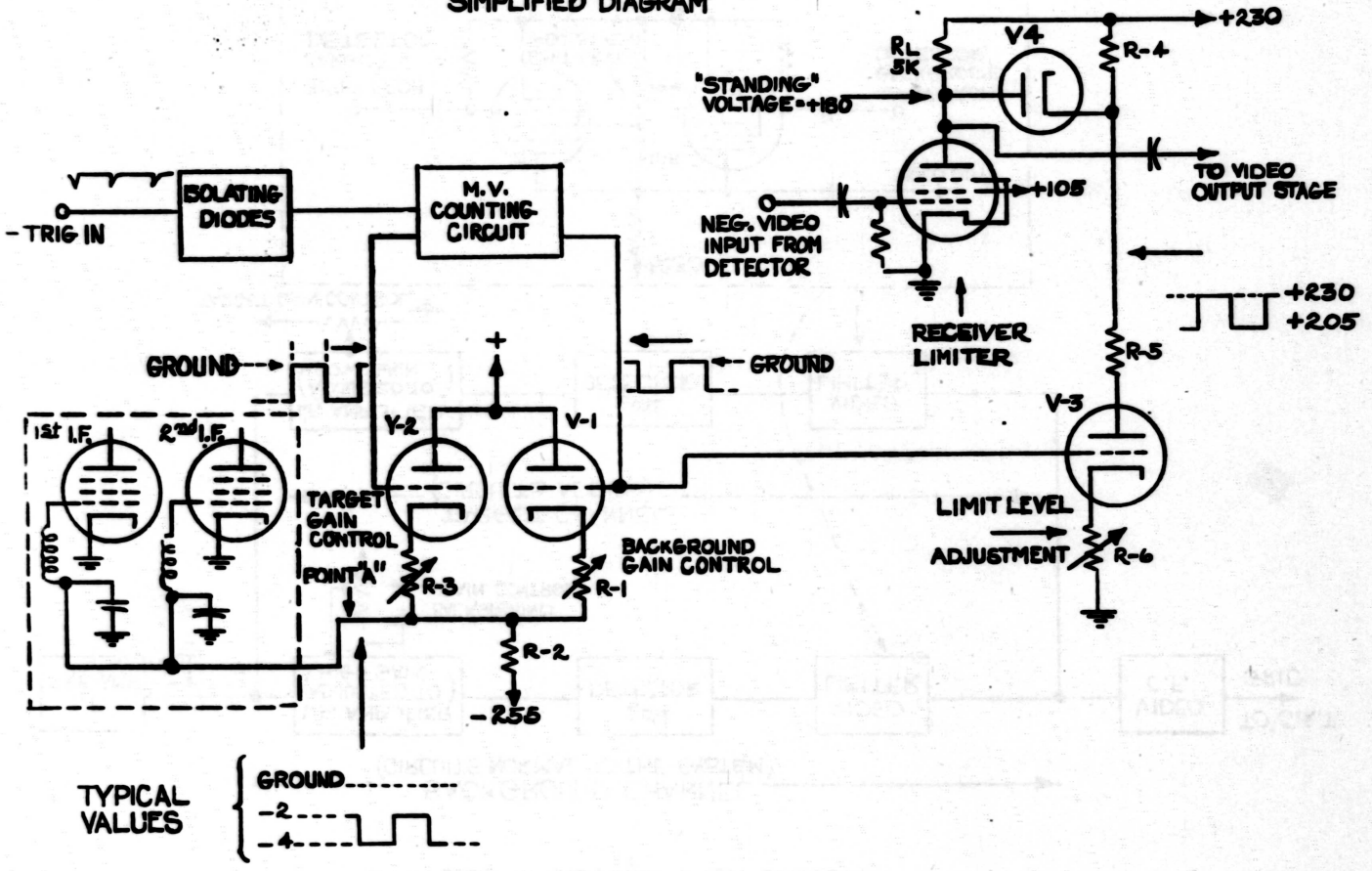

FIG 3

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BLOCK DIAGRAM OF "TWO RECEIVER" METHOD OF THREE TONE P.P.I.
AS APPLIED TO THE AN/APS 15A SYSTEM

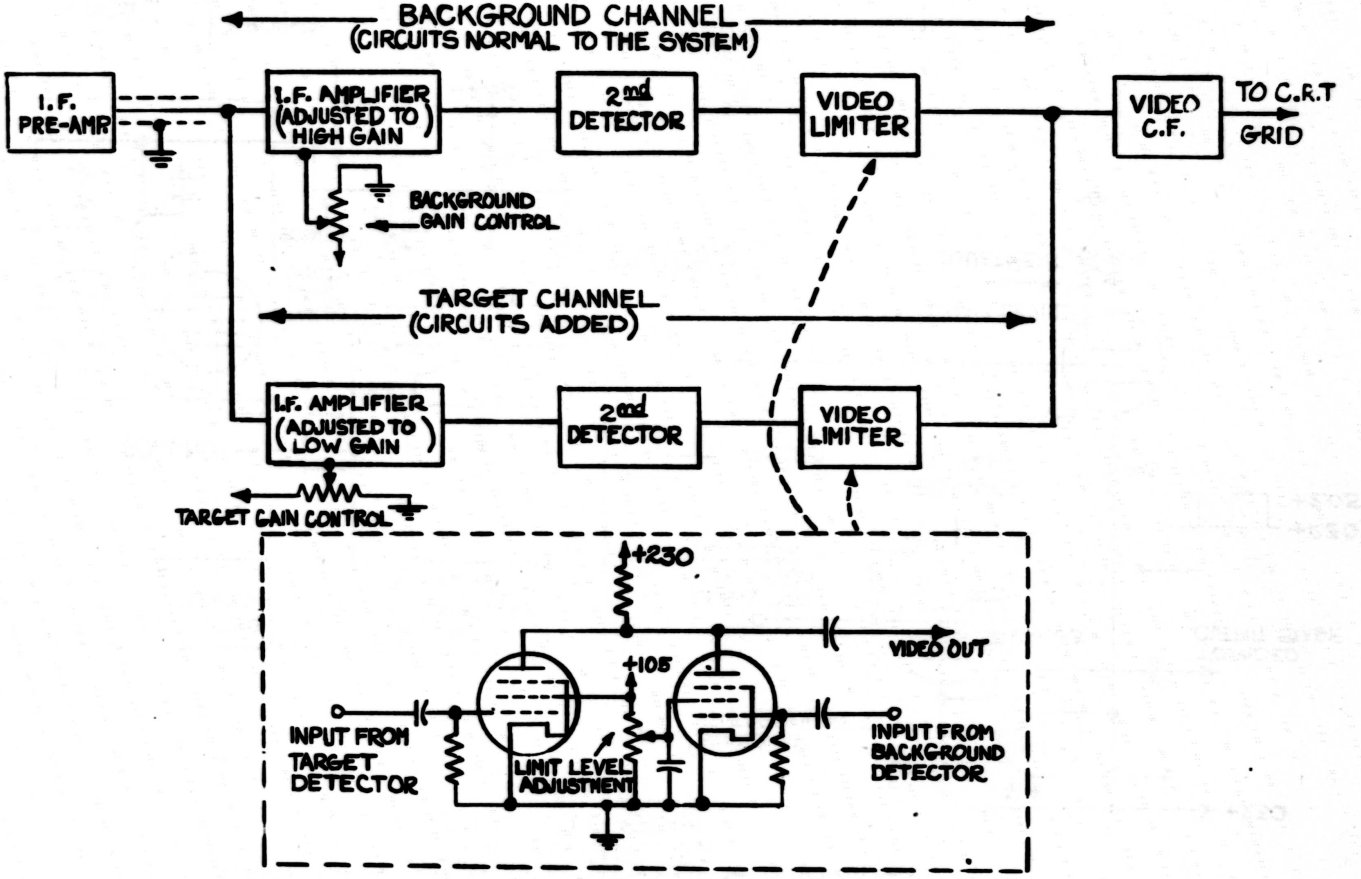


FIG. 4

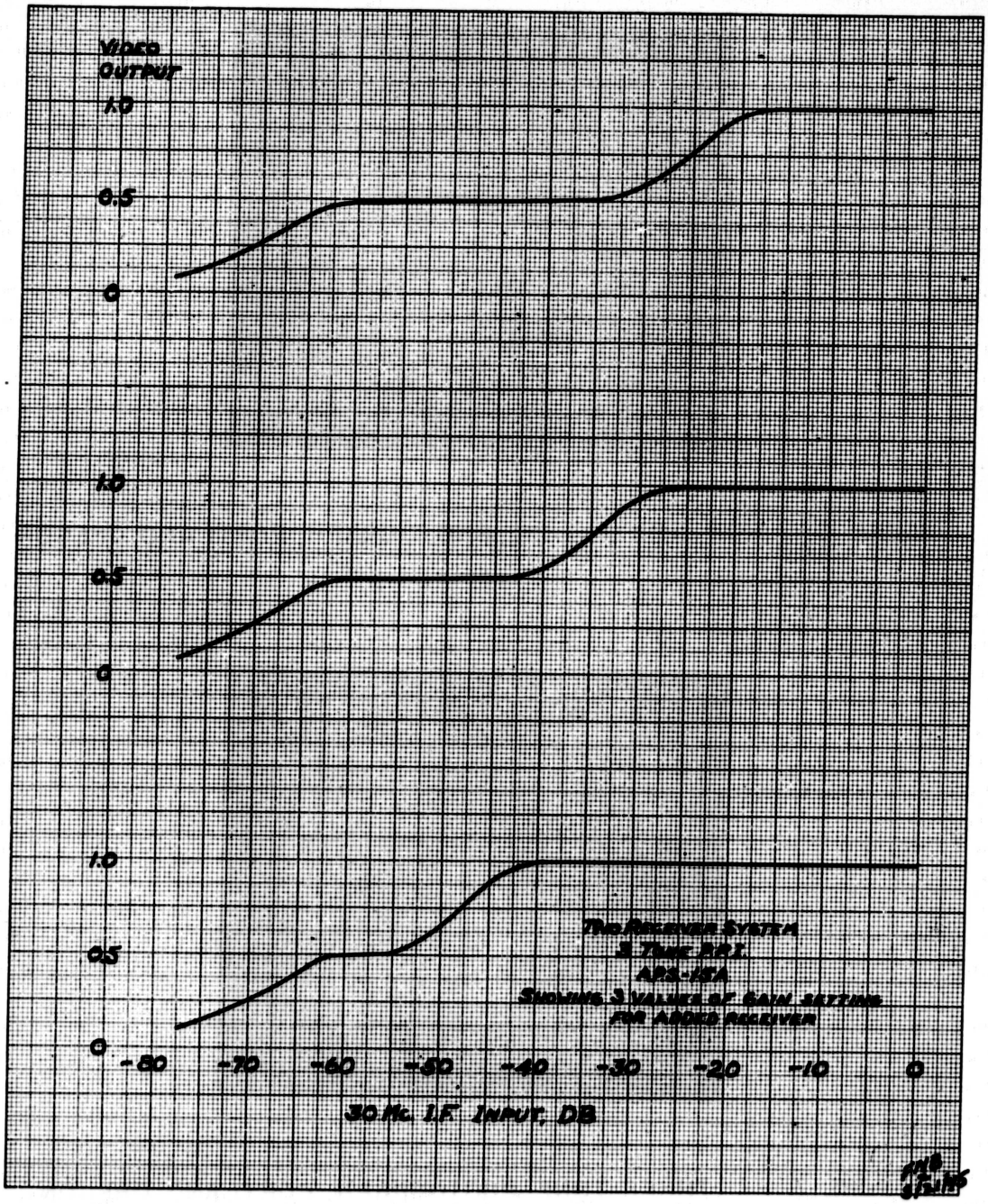

VIDEO OUTPUT
1.0
0.5
0
1.0
0.5
0
1.0
0.5
0
-80
-70
-60
-50
-40
-30
-20
-10
0
30 Mc. I.F. INPUT, DB
THE RECEIVER SYSTEM
S.TRUC. R.C.I.
APS-10A
SHOWING 3 VALUES OF GAIN SETTING
FOR MICRO RECEIVER

Fig. 5

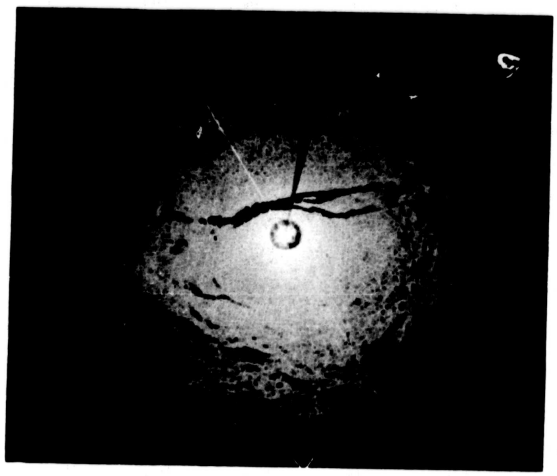


FIGURE 6 NON-THREE TONE PHOTOGRAPH, PORTLAND, OREGON

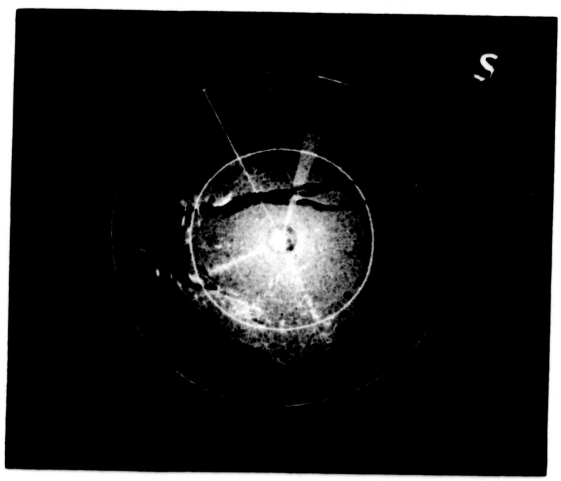


FIGURE 7 THREE TONE PHOTOGRAPH, PORTLAND, OREGON

FIGURE 8 THREE TONE PHOTOGRAPH, BOSTON, MASS.

FIGURE 9 SAN FRANCISCO BAY AREA, THREE TONE PHOTOGRAPH

FIGURE 10 THREE TONE PHOTOGRAPH OF GARY, EAST CHICAGO REGION

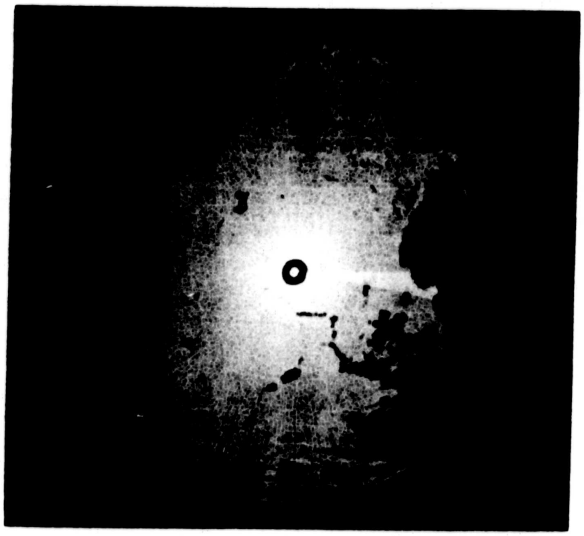


FIGURE II BOSTON, MASS. AREA, NON-THREE TONE PHOTOGRAPH

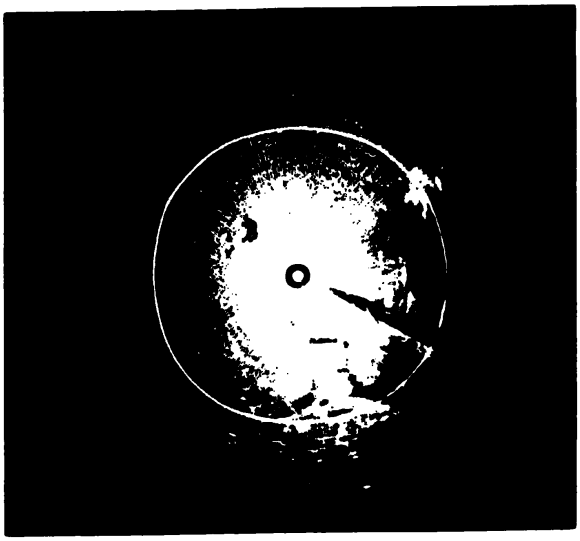
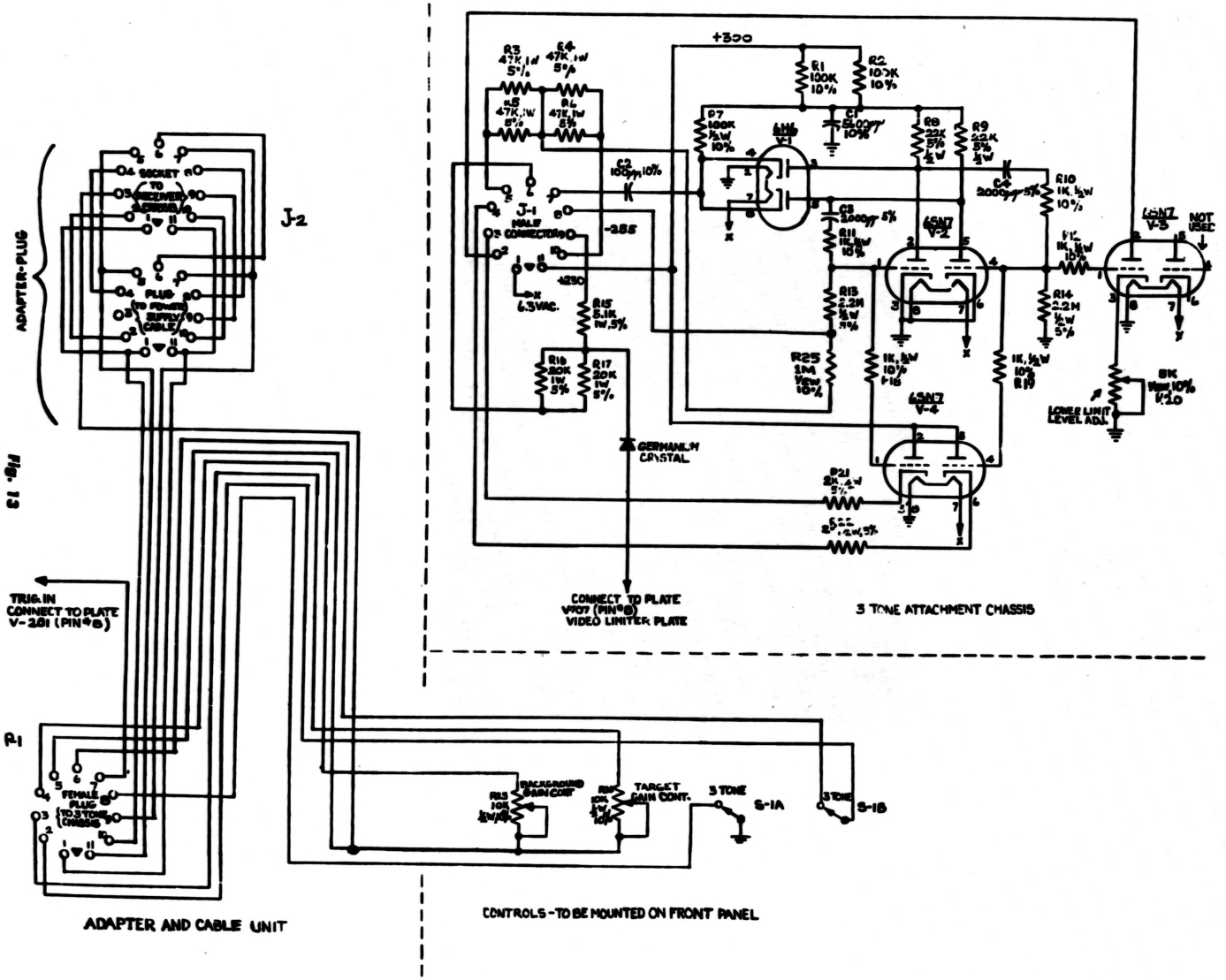


FIGURE 12 BOSTON, MASS. AREA, THREE TONE PHOTOGRAPH

3 TONE ATTACHMENT FOR ANARC-13A

Fig. 13



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Barry, F. N.

AUTHOR(S)

DIVISION: Electronics (3)
SECTION: Radar (2)
CROSS REFERENCES: Plan position indicators (71875)

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ORIGINATING AGENCY: Massachusetts Inst. of Technology, Radiation Lab., Cambridge

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U.S.	Eng.		Unclass.	Mar'46	20	13	photos, diagrs, graphs

ABSTRACT

Three-tone PPI is intended to overcome a limitation in the usual presentation of a radar picture by providing one limit level for general land signals and another for more prominent targets. This is accomplished either by time division method or by methods which divide, separately amplify, and later mix the two classes of signals. Hence, water is black, general land return is indicated as gray, and the stronger signals from cities, etc., are indicated as white, which gives a composite picture in contrasting brightness.

AP-3-2-40

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March '46	Unclass.	U.S.	Eng.	21	photos, diagr, graphs

ABSTRACT:

A method to overcome a limitation of a radar picture on the screen of a cathode ray tube is described. The three-tone PPI overcomes this limitation in part by providing two limit levels; one for general land signals, and one for the more prominent targets. This is accomplished by either a time division method or by methods which divide, separately amplify, and later mix the two classes of signals. The result is a composite picture which shows general land signals and built up areas contrasting in brightness on the cathode ray tube. The range of signals, was found to center around twenty db difference between those signals which would normally be termed land background and those which would be termed "bright" under typical adjustments.

(25) PPI (Plane Position Indicator

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Air Documents Division, Intelligence Department
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